



Overview of the Accelerated Insertion of Materials – Composites (AIM-C) Producibility Module Development



Presented at
SAMPE – May, 2002

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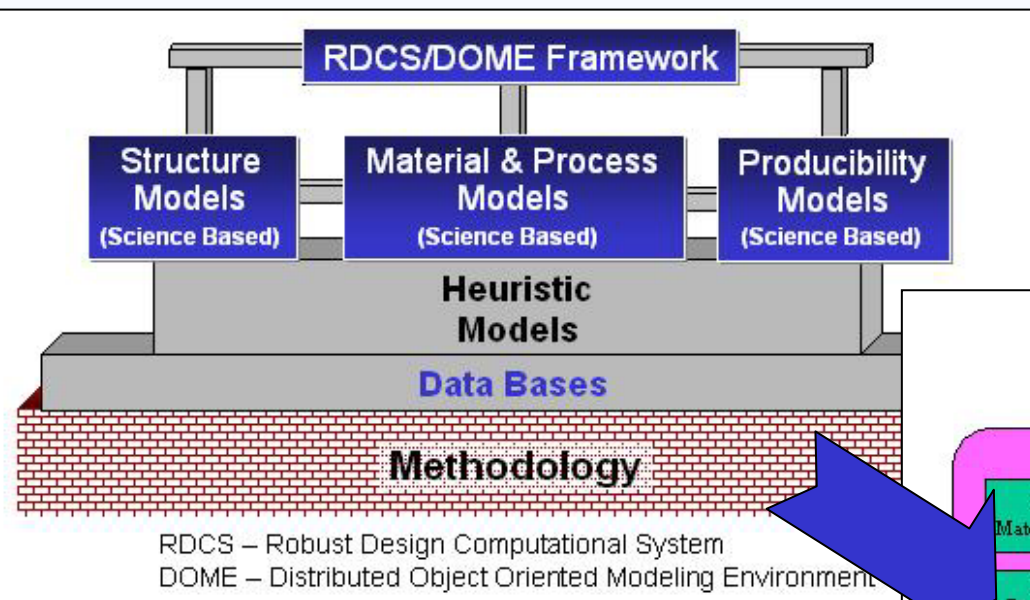
**Jointly accomplished by BOEING Led Team and the U.S. Government
under the guidance of NAST**

*This program was developed under the guidance of Dr. Steve Wax and
Dr. Leo Christodoulou of DARPA. It is under the technical direction of
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Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE MAY 2002		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Overview of the Accelerated Insertion of Materials Composites (AIM-C) Producibility Module Development				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Boeing Phantom Works				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 23	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

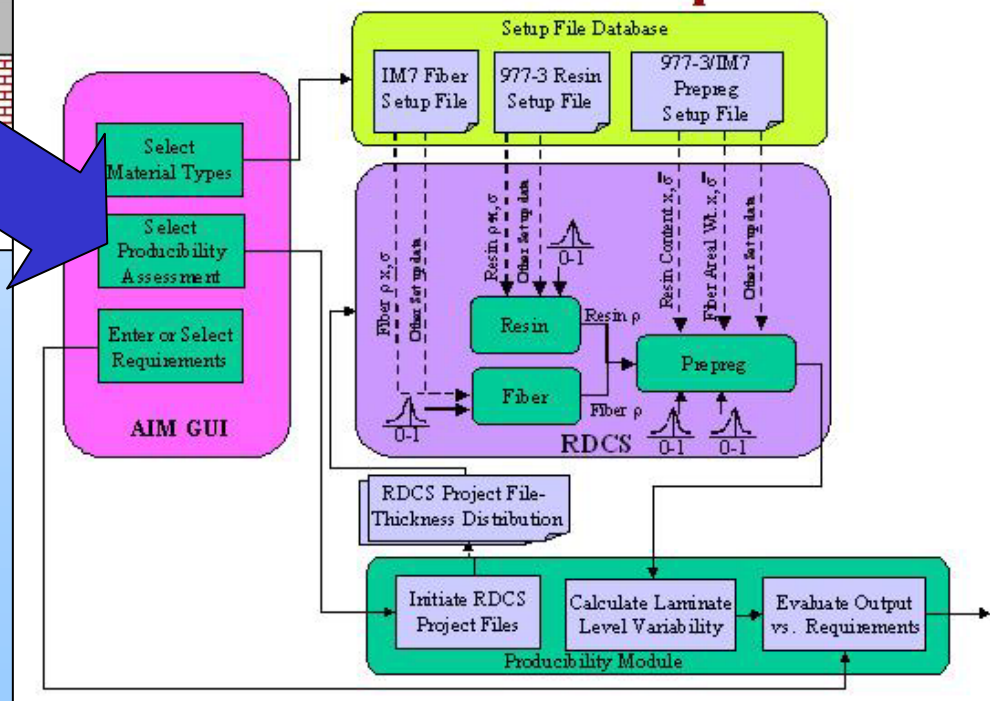


Overall Program Plan



RDCS – Robust Design Computational System
DOME – Distributed Object Oriented Modeling Environment

Architecture Example





Producibility Module Software



Most aspects of producibility are very subjective and/or based on previous experience with very little existing software. Therefore, it is being proposed existing software capable of logical programming along with data bases that will contain pertinent information to be interrogated through SQL.

- **Heuristic and/or Rule Based Software**
(**Java**, Visual Basic, C++....)
- **Knowledge/Data Bases**
(Access, **Oracle**, M-Vision,...)
- **Science Based Objective Models**
(Fortran, C++, etc.)
 - **CACC** (**Thickness**, Voids/Porosity, Resin Flow Bagging, Debulking, **Tooling**, etc.)



Producibility Module Definitions



Definition:

A Controller Module to Compare Requirements to Manufacturing Capabilities For Quality Components

Corollaries:

- ***Can I Make It?***
 - ***With What Degree of Success?***
 - ***How Can I Make It?***
 - ***By Which Manufacturing Sequence Should It Be Made?***
- **The Initial Envisioned Module Provides Heuristics Which Give Guidance Through Part Thermal Processing (Cure/Post Cure)**
 - **Does Not Include Hole Drilling or Assembly in Basic Program**
- **For purposes of Bookkeeping in the AIM-C CAT Program, It Also Includes What Hasn't Been Addressed in Other Areas**



Producibility Module Definitions



Additional Definitions:

➤ **Manufacturing Capabilities**

- Ability to Fabricate the Unassembled Components with Identified Materials and Manufacturing Methods

➤ **Manufacturing/Processing Steps/Areas**

- Ply Cutting
- Layup
- Debulking
- Bagging
- Equipment
- Tooling
- Repairability

➤ **Quality Requirements/Parameters**

- Meets Functional Requirements (Strength, Stiffness, Dimensions, Etc.)
- Requirements/Parameters are Identifiable, Measurable, and Boundable

➤ **Component Quality Requirements/Parameters**

- Dimensions
- Voids
- Porosity
- Inclusions
- Surface Waviness
- Fiber Volume/Resin Content
- In-Plane & Out of Plane Fiber Distortion
- Surface Finish

➤ **In-Process Quality Requirements/Parameters**

- Ply Angle
- Ply Lap/Gap
- Out Time
- Freezer Time
- Equipment Certifications
- Heat-up Rates
- Cure Time, Temp, Pressure
- Abort Conditions
- Debulk Time, Temp, Pressure



Module Functional Flow Chart



Design User Requirements

- Kind of Structure (Skins, Substructure, Doors, Etc.)
- Class of Structure (Primary, Secondary, etc.)
- Type of Structure (Monolithic, Cocure, Etc.)
- Configuration/Features
- Tolerances
- Fiber/Fiber Form
- Fiber Volume/Resin Content
- Quality (Voids, etc.)
- Additional Mat'l's
- Secondary Operations
- Repairability
- Manufacturing Methods

Other User Requirements

Certification User Requirements

- Changed Mat'l, Process, Equipment, Tooling

CAD Master
Data Tie

Modules/RDCS

- Resin
- Fiber
- Prepreg
- Processing
- Lamina
- Structure
- Durability

Variability/
Error Analysis
Results

Key Mat'l
& Process
Controls

Knowledge Bases

- Lessons Learned
- Structure Kind, Type..
- Configuration
- Parts
- Secondary Operations
- Repairability
- Sourcing Capabilities/Capacities
- Equipment
- Tooling
- Quality
- Test Methods

**Producibility
Module**

Methodology
(Divergence/Risk)

CACC

CAICAT, ATMCS,
FiberSim, Panform

Outputs

- Divergence/Risk for Requirements Relative to Capabilities
- Risk Reduction Recommendations
- Costs/Times
- Design/Manufacturing Recommendations
- Mat'l & Process Spec Recommendations
- Quality Plan/Recommendations
- Indirect Materials
- Tooling Definitions/Concepts



Knowledge/Data Bases



Manufacturing/Processing Steps

- Cutting
- Layup
- Debulking
- Cure
- NDE/Quality
- Testing

Equipment

- Cutting
- Collation
- Ovens
- Autoclaves
- NDE
- Testing

Lessons Learned

- Configuration/Type/Class (Parts)
- Methodology
- Material(s) and Material Combinations
- Manufacturing/Processing Steps
- Tooling
- Equipment
- Quality (In-process and Final Part)
- Testing/Evaluations
- Secondary Operations
- Repair
- RDT&E Costs/Times?

Tooling

- Primary Tooling
- Secondary Tooling

Secondary Operations

- Bonding
- Painting
- Coating

Repair

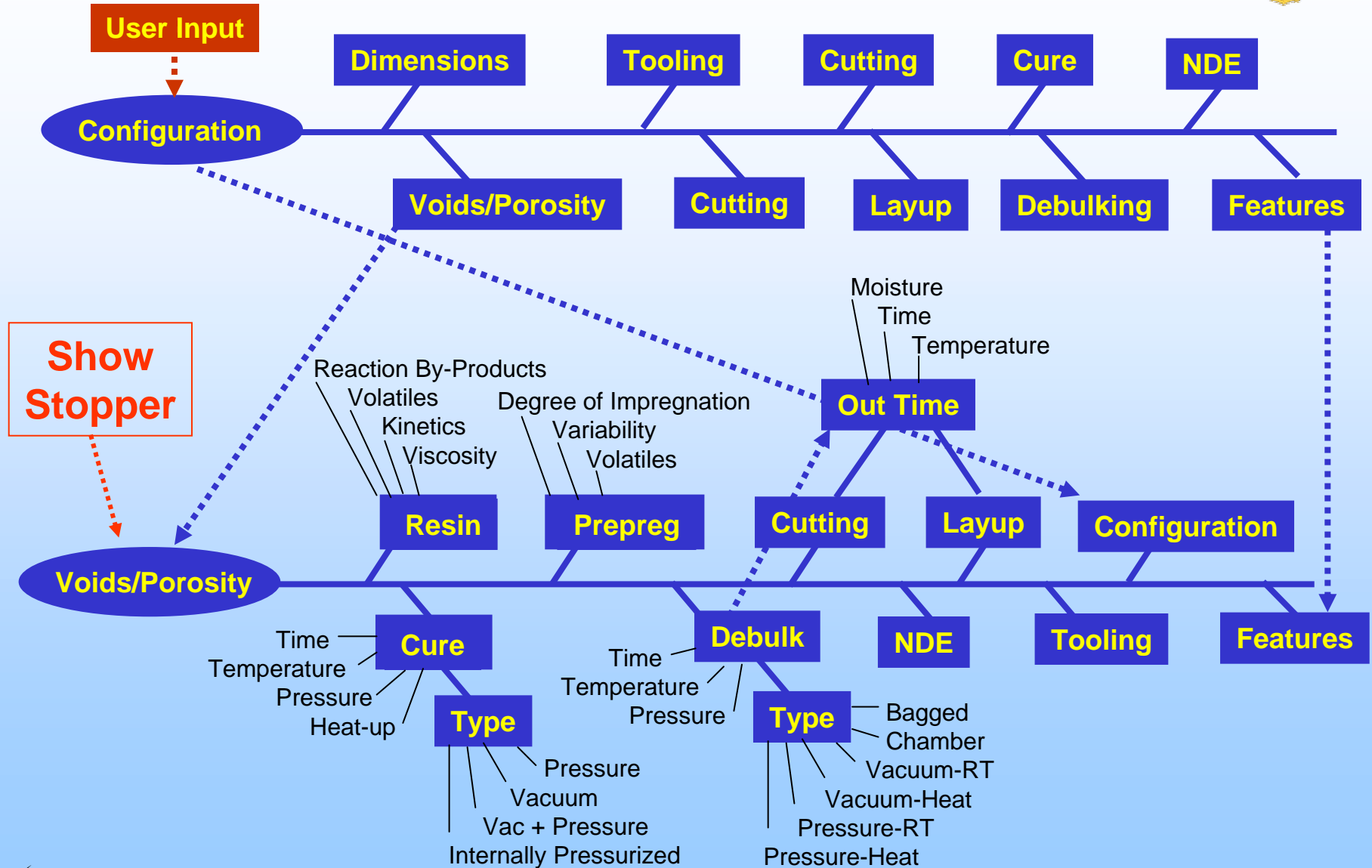
- In-process
- Final Part (After Cure)
- Material Compatibility

Other

- Health & Safety
- ITAR
- Proprietary Info



Cause and Effect Diagrams

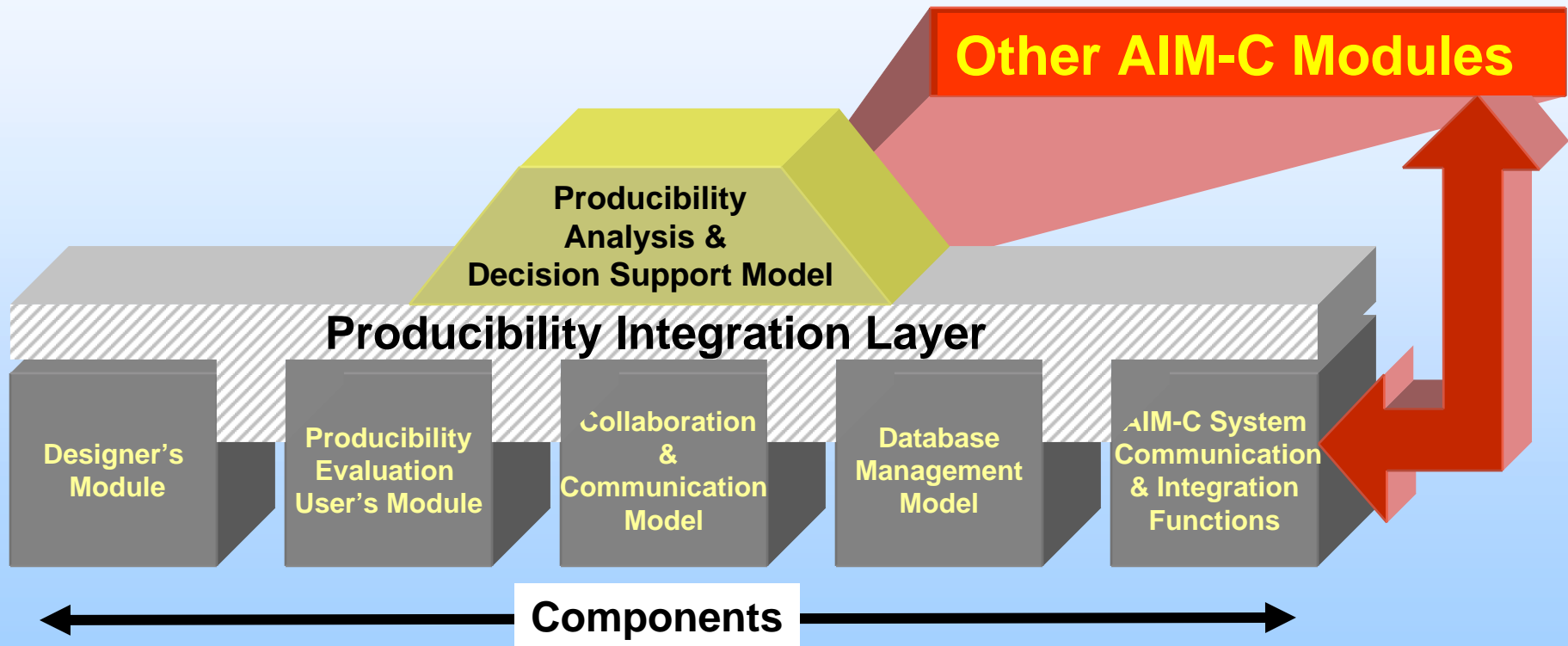




AIM-C Producibility Module



Producibility Module Has Integrated Components That In Turn.....



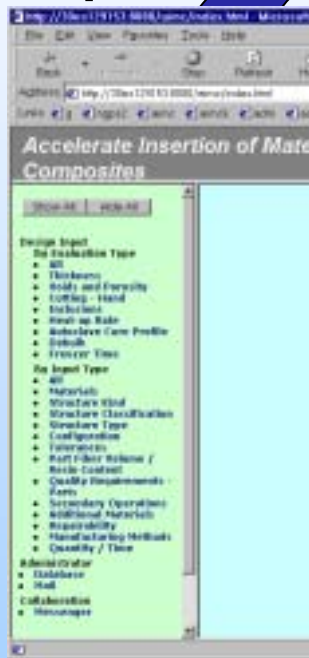
.....Are Integrated With Other AIM-C Modules



Producibility Module Demo Overview



Design User
Inputs



- Primary Matl's
- Size/Thickness
- Features
- Tolerances
- Quality Requirements

Producibility
Item(s)
Evaluation



- Thickness
- Voids/Porosity
- Cutting
- Indirect Matl's

Knowledge/Data
Bases

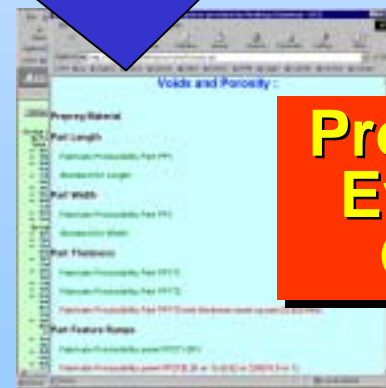
Referenced/
Required
Information

Lessons
Learned

Indirect
Materials

Testing/
Specs

Producibility
Evaluation
Outputs





Starting Module Design User



- **Control of Users**
- **Multiple User Types**
- **Administration Control for Data Bases**
- **Design User Variables for Producibility**
- **Producibility Evaluations From a Design User Standpoint**
- **Producibility Evaluations From a Producibility User Standpoint**

User Login

Username

Password

Enter your login and password, then hit Login.

Login Clear

Accelerated Insertion

Show All Hide All

Design User

- Design User Input
 - All
 - Materials
 - Structure Kind
 - Structure Classification
 - Structure Type
 - Configuration
 - Tolerances
 - Part Fiber Volume / Resin Content
 - Quality Requirements - Parts
 - Secondary Operations
 - Additional Materials
 - Repairability
 - Manufacturing Methods
 - Quantity / Time
- Producibility Evaluation
 - All
 - Thickness
 - Voids and Porosity
 - Cutting - Hand
 - Inclusions
 - Heat-up Rate
 - Autoclave Cure Profile
 - Debulk
 - Freezer Time
- Producibility User
 - Design Input
 - Producibility User Variables
- Administrator
 - Database
 - Mail
 - Collaboration
 - Messenger

Double clicks to collapse / expand this menu from



Design User Inputs



Design User Definable Variables

- Design User Sets Problem/Requirements For Producibility Evaluations
- Ties to Other Design User Items
- Allows Individual Producibility Item Evaluations or All Items

Materials

Resin 1:	Type:	977-3	Form:	SHS	Kind:	AS4
Fiber 1:	Type:	3K				
PrePreg 1:	Type:	graphite epoxy	Resin Content		Areal Weight	
Resin 2:	Type:	977-3				
PrePreg 2:	Type:					
Resin 3:	Type:					
Fiber 3:	Type:					
PrePreg 3:	Type:					
Resin 4:	Type:	977-3				
Fiber 4:	Type:	3K				
PrePreg 4:	Type:	graphite epoxy				

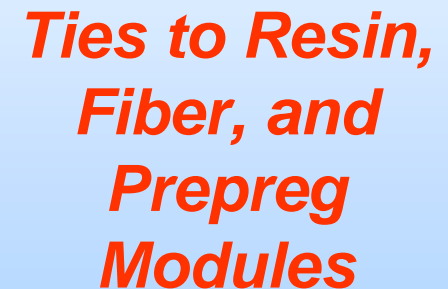
Structure Kind

Skin(s)

Structure Kind

Fairings

***Producibility Evaluations/Outputs
According to User Inputs/Requirements***





Producibility – Quality: Thickness



Thickness for Producibility Evaluation

	Avg	Min	Max
Number of Piles	N/A	25	76
Per Ply Thickness	0	0	0
Min Part Thickness	0	0	0
Max Part Thickness	0	0	0

Problem: min part thickness is 0
Problem: max part thickness is 0

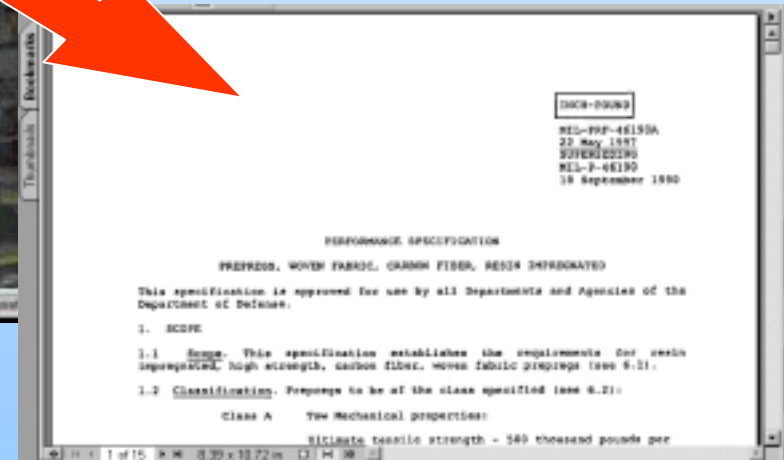
View Test Method

Testing

**Multiple Output
Options and
Information**

Specifications

**Identification of
Potential
Problems**





Producibility – Quality: Voids



Show All Hide All

Design User

- Design User Input
 - All
 - Materials
 - Structure Kind
 - Structure Classification
 - Structure Type
 - Configuration
 - Tolerances
 - Part Fiber Volume / Resin Content
 - Quality Requirements - Parts
 - Secondary Operations
 - Additional Materials
 - Repairability
 - Manufacturing Methods
 - Quantity / Time
- Producibility Evaluation
 - All
 - Thickness
 - Voids and Porosity
 - Cutting - Hand
 - Inclusions
 - Heat-up Rate
 - Autoclave Cure Profile
 - Debulk
 - Freezer Time
- Producibility User Design Input
 - All

Voids and Porosity Relative to Size, Thickness, and Feature Ramps

Please specify part parameters and click Calculate :

Calculate Open Save

Prepreg:	Resin Type	977-3		
	Fiber Type	3K		
	Prepreg Type	graphite epoxy		
Length:	Minimum (in):		Maximum (in):	
Width:	Minimum (in):		Maximum (in):	
Thickness:	Minimum (in):		Maximum (in):	
Ramps:	Min Thickness (in):		Max Thickness (in):	
	Ramp Ratio:		Step Thickness (in):	
Max. Void %				



Producibility – Quality: Voids



Voids and Porosity :

Prepreg Material

Part Length

Fabricate Producibility Part PP1 (view).

Standard for Length

Part Width

Fabricate Producibility Part PP1 (view).

Standard for Width

Part Thickness

Fabricate Producibility Part PP1T1 (view) and Thin test panel (0.0) inches thick.

Fabricate Producibility Part PP1T2 (view).

Fabricate Producibility Part PP1T3 (view) and thickness scale-up part (0.0) thick.

Part Feature Ramps

Fabricate Producibility panel PP2T1-2R1 (view).

Fabricate Producibility panel PP2T(0.0 or 1)-(0.0 or 2)R(0.0 or 1) (view).

Part Quantity - Voids

NDE Standards (Effect of Defect)

Fabricate NDE standard part PP_NDE2 (view) with (0.0 %) voids.

Fabricate NDE standard part PP_NDE2 (view) with 2X(0.0 %) voids.

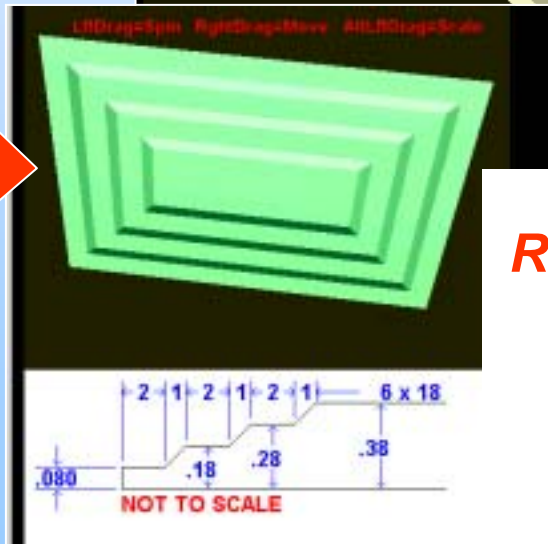
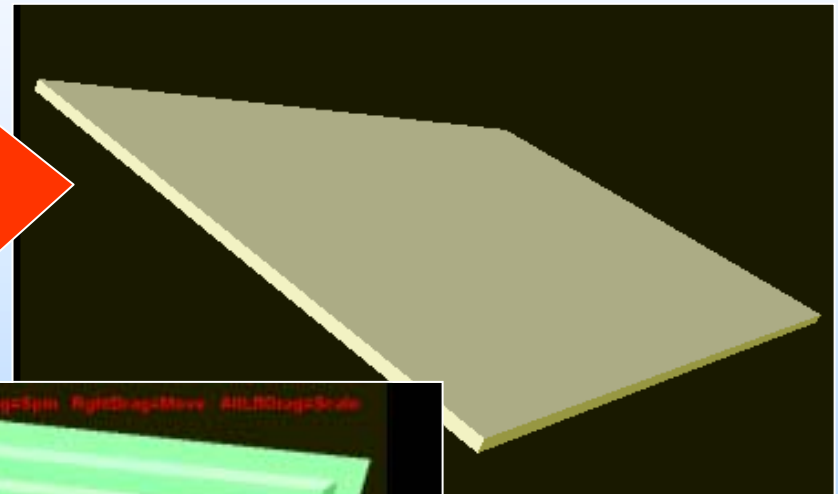
Fabricate NDE standard part PP_NDE2 (view) with 3X(0.0 %) voids.

Mechanical Property Panels (Effect of Defect)

Fabricate Compression test Panel(s) CTP1 (view) with (0.0 %) voids.

Fabricate Compression test Panel(s) CTP1 (view) with 2X(0.0 %) voids.

Fabricate Compression test Panel(s) CTP1 (view) with 3X(0.0 %) voids.



**Output
Recommendations
Based on User
Inputs, Std
Produce Tests,
and Lessons
Learned**





Producibility – Method: Cutting



Producibility User Design Input

- All
- Materials
- Structure Kind
- Structure Classification
- Structure Type
- Configuration
- Tolerances
- Part Fiber
- Volume / Resin Content
- Quality Requirements - Parts
- Secondary Operations
- Additional Materials
- Repairability
- Manufacturing Methods
- Quantity / Time

Producibility User Variables

- All
- Thickness
- Voids and Porosity
- Cutting - Hand
- Inclusions
- Heat-up Rate
- Autoclave
- Cure Profile
- Debulk
- Freezer Time

Administrator Collaboration

Cutting - Hand

Please specify Product Name and click Calculate :

Calculate **Open** **Save**

Resin:	Type:	977-3			
Fiber:	Type:	3K	Form:	5HS	Kind: AS4
Backing Paper:	Product Name:	Product A			
Separator Material:	Product Name:	Product A			
Spool Requirements:	Facility:	Boeing	Weight(lbs):	10	Diameter(Inches): 5 Width(Inches): 100
Resin Environment Requirements:	Storage greater than 5'				
Part Quality:	Inclusions:	Cutting			
In process Quality:	Angle Accuracy:	Facility:	Boeing	Cutting Angle Accuracy:	overall average

Methods Take Into Account Facilities/Capabilities, Direct Materials, Indirect Materials, Part Quality, In-Process Quality, and Interactions With Other Items



Producibility – Method: Cutting



Results for Cutting - Hand

Prepreg Material - Indirect Materials

Backing Paper

Product A associated with Prepreg

Evaluate prepreg backing paper per??? Specification for NDE detectability and contamination.

Product A associated with NDE Compatibility

Evaluate prepreg backing paper per??? Specification for contamination.

Separator Material

Evaluate prepreg separator per??? Specification for prepreg usage.

Product A associated with ResinID 1

Product A associated with NDE Compatibility

Evaluate prepreg separator per??? Specification for prepreg usage, NDE detectability, and contamination.

Prepreg Material - Spool Requirements

Cutting Capability

There is a conflict between cutting capabilities and prepreg spool ???, Needs investigation.

Resin Environment Requirements

Prepreg Material - Spool Requirements

Cutting Capability

There is a conflict between cutting capabilities and prepreg spool ???, Needs investigation.

Resin Environment Requirements

TBD.

Part Quality - Inclusion

Indirect Materials - Cutting

Product A associated with Cutting

Evaluate cutting separator per??? Specification for prepreg usage.

Product A associated with NDE Compatibility

Evaluate cutting separator per??? Specification for prepreg usage, NDE detectability, and contamination.

In-process Quality - Angle Accuracy

Angle accuracy capability (total layup angle accuracy/repeatability) can not meet quality requirements of [angle accuracy] because cutting accuracy/repeatability is ?? And layup accuracy/repeatability is ??.

Secondary Operations

ttest per ??? Specification

Part Dimensions



Producibility User Producibility – Quality: Thickness



Producibility User
Design Input

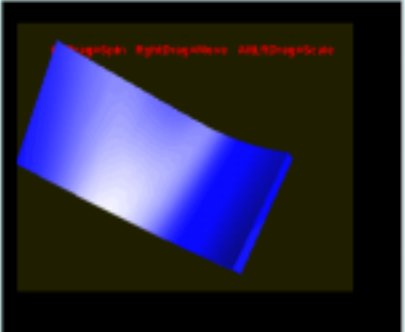
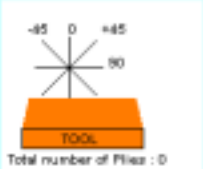
- All
- Materials
- Structure Kind
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- Configuration
- Tolerances
- Part Fiber
- Volume / Resin Content
- Quality Requirements - Parts
- Secondary Operations
- Additional Materials
- Repairability
- Manufacturing Methods
- Quantity / Time

Producibility User Variables

- All
- Thickness
- Voids and Porosity
- Cutting - Hand
- Inclusions
- Heat-up Rate
- Autoclave Cure Profile
- Debulk
- Freezer Time

Administrator Collaboration

Thickness for Producibility User Variables



Please specify part parameters and click Calculate :

Calculate **Open** **Save**

Tolerance Requirements

Tolerance Values		Norm:	Min:	Max:
Ply Set 1:	# of Plies:		Orientation:	0 0
PrePreg 1:	Type:	graphite epoxy		
Fiber 1:	Type:	3K	Form:	SHS Kind: AS4
Resin 1:	Type:	977-3		

**The Module Is
Flexible So Different
Users Can Use It
For Their Needs
Later In a
Development Cycle**



Producibility User Producibility – Quality: Thickness



Producibility User
Design Input

- All
- Materials
- Structure Kind
- Structure Classification
- Structure Type
- Configuration
- Tolerances
- Part Fiber
- Volume / Resin Content
- Quality Requirements - Parts
- Secondary Operations
- Additional Materials
- Repairability
- Manufacturing Methods
- Quantity / Time

Producibility User Variables

- All
- Thickness
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- Cutting - Hand
- Inclusions
- Heat-up Rate
- Autoclave Cure Profile
- Debulk
- Freezer Time

Administrator Collaboration

Total number of Plies : 12

Please specify part parameters and click Calculate :

Calculate **Open** **Save**

Thickness for Producibility User Variables

Thickness	Min	Max	Avg	Range
Part	0.167646	0.16918	0.163366	0.011534
per ply (set 1)	0.013137	0.014098	0.013613	0.000961
per ply (set 2)	0.013137	0.014098	0.013613	0.000961
per ply (set 3)	0.013137	0.014098	0.013613	0.000961
per ply (set 4)	0.013137	0.014098	0.013613	0.000961

Good: thickness variations within tolerance

Visual Method

Tolerance Requirements

Tolerance Values	None	Min	Max
Ply Set 1:	# of Plies: 3	Orientation: -45	45
PrePreg 1:	Type: graphite epoxy		
Fiber 1:	Type: 3K	Form: SHS	Kind: AS4
Resin 1:	Type: 977.3		
Ply Set 2:	# of Plies: 4	Orientation: 90	90

**Output According
To Needs**



Administrator User Data Base Management



Please select a database

You are editing AIMC Database. You can select and view any table, or run any SQL query.

Driver:

URL: (must be in a form the driver understands)

Login:

Password:

Tables found

You are connected to relational database, driver is sun.jdbc.odbc.JdbcOdbcDriver

Choose table

Filter
FiberDens
FiberForm
FiberKied
FiberType
FiberYield
Inclusion
KineticModel
Part
Pow
Prepreg
Raw
Re
Resin

To execute a SQL query, enter it below, or choose from the list of previously run queries on the right.

**Maintainability
and Information
Updating Is
Critical....**



Collaboration User Messenger



Categories:

- Inclusions
- Heat-up Rate
- Autoclave Cure Profile
- Debulk
- Freezer Time

Producibility User Design Input

- All
- Materials
- Structure Kind
- Structure Classification
- Structure Type
- Configuration
- Tolerances
- Part Fiber Volume / Resin Content
- Quality Requirements - Parts
- Secondary Operations
- Additional Materials
- Repairability
- Manufacturing Methods
- Quantity / Time

Producibility User Variables

- All
- Thickness
- Voids and Porosity
- Cutting - Hand
- Inclusions
- Heat-up Rate
- Autoclave Cure Profile
- Debulk
- Freezer Time

Administrator

- Database
- Mail

Collaboration

- **Messenger**

Al Burrows
AIMC Guru

Areas of Ownership:
Cutting - Hand

Address Book:

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- Phone: (310)123-4567
- Address: 888 West 190th St, Suite 888
- Department: YB99/UNK



Summary



- ***Demonstrated:***
 - Design User Interface for Producibility
 - Producibility Quality Areas of Thickness and Voids
 - Producibility Operation/Processing Area of Cutting and Indirect Materials
 - Recommendations Based on Inputs and Lessons Learned
 - Integration of Producibility Module Multiple Component Pieces
- ***Approach Is Viable As Module Has Evolved***